CH2M-36345-FP
Revision 0

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Prepared for the U.S. Department of Energy
Assistant Secretary for Environmental Management

Contractor for the U.S. Department of Energy
Office of River Protection under Contract DE-AC27-99RL14047

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Date Published
February 2008

To Be Presented at
Waste Management 2008 Conference

Waste Management Symposia, Inc.
Phoenix, Arizona

February 24-28, 2008

Published in
Proceedings of 2008 Waste Mangement Conference

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## ABSTRACT

CH2M HILL Hanford Group, Inc. (CH2M HILL) plays a critical role in Hanford Site cleanup for the U. S. Department of Energy, Office of River Protection (ORP). CH2M HILL is responsible for the management of 177 tanks containing 53 million gallons of highly radioactive wastes generated from weapons production activities from 1943 through 1990. In that time, 149 single-shell tanks, ranging in capacity from 50,000 gallons to 500,000 gallons, and 28 double-shell tanks with a capacity of 1 million gallons each, were constructed and filled with toxic liquid wastes and sludges. The cleanup mission includes removing these radioactive waste solids from the single-shell tanks to double-shell tanks for staging as feed to the Waste Treatment Plant (WTP) on the Hanford Site for vitrification of the wastes and disposal on the Hanford Site and Yucca Mountain repository.

Concentrated efforts in retrieving residual solid and sludges from the single-shell tanks began in 2003; the first tank retrieved was C-106 in the 200 East Area of the site. The process for retrieval requires installation of modified sluicing systems, vacuum systems, and pumping systems into existing tank risers. Inherent with this process is the removal of existing pumps, thermo-couples, and agitating and monitoring equipment from the tank to be retrieved. Historically, these types of equipment have been extremely difficult to manage from the aspect of radiological dose, size, and weight of the equipment, as well as their attendant operating and support systems such as electrical distribution and control panels, filter systems, and mobile retrieval systems. Significant effort and expense were required to manage this new waste stream and resulted in several events over time that were both determined to be unsafe for workers and potentially unsound for protection of the environment.

Over the last four years, processes and systems have been developed that reduce worker exposures to these hazards, eliminate violations of RCRA storage regulations, reduce costs for waste management by nearly 50 percent, and create a viable method for final treatment and disposal of these waste forms that does not impact retrieval project schedules.

This paper is intended to provide information to the nuclear and environmental clean-up industry with the experience of CH2M HILL and ORP in managing these highly difficult waste streams, as well as providing an opportunity for sharing lessons learned, including technical methods and processes that may be applied at other DOE sites.

## HISTORY OF REMOTE HANDLED AND LONG LENGTH WASTES AT THE HANFORD TANK FARMS

Removal of long length and oversized equipment at the tank farms commenced to become an important issue in 1994. At that time, tank SY-101, located in the 200 West Area of the Hanford Site, began to experience a series of events due to gas generation in the tank bottom. These "roll-over" events posed a major concern as they released hydrogen gas, a hazard that required mitigation. As part of the corrective actions, a mixer pump was installed in tank SY-101 to better assure a mixing of the tank contents and removal of hydrogen gas build-up at a controlled rate. This project was a success, but the outfall was the generation of large pieces of equipment that required management when they were removed to support the mixer pump and support system installation. Since the application of Land Disposal Restriction (LDR) treatment standards was relatively new, the only viable alternative at the time was to package the material for storage. Large steel tubes were designed and manufactured. Three air lances removed from SY-101 were placed. This process created three packages nearly 21 meters (70 feet) in length, 1 meter (3 feet) in diameter, and weighing nearly 13 tons. Simply moving them into compliant storage at the Hanford Site Central Waste Complex (CWC) was hazardous. The packages were hard to manipulate and access to storage was not designed for packages of this type.

DOE recognized that alternative methods for managing such wastes were not only necessary, but critical to assuring the progress of tank farm cleanup activities into the future. Several engineering studies were conducted in coordination with regulatory authorities to identify alternative methods, technologies, and processes for managing the difficult waste forms. Coinciding with these efforts, established methods for alternative treatment of these waste forms under the Resource Conservation and Recovery Act of 1976 (RCRA) were promulgated. One such method of alternative treatment was macro-encapsulation technology. Since the air-lances had been stored in a heavy duty packaging system to reduce dose consequence and assure transportation safety, LDR treatment in the storage package could be accomplished and meet LDR requirements. The air lance packages were removed from the CWC, transported to the T plant complex for treatment via macro-encapsulation using high flow grout, welding, and epoxy paints for external package corrosion controls. This effort was accomplished successfully, but several lessons were learned: the process could only be completed outdoors due to the size of the equipment; welding was difficult to perform due to the package configuration and created safety and exposure issues for personnel; the high flow grout process was difficult to demonstrate meeting full encapsulation criteria based on calculation alone; and costs for the process were extremely high as compared to the appreciable gain in environmental protection.

To further exacerbate the matter, studies indicated that major facility modifications, or new facilities, were required to manage these waste forms. Life cycle cost estimates ranged from approximately $360 million to nearly $565 million to create facilities with the ability to manage treatment of such large and high dose waste forms. Clearly, those alternatives would be faced with a myriad of technical and regulatory challenges that would drive costs even higher than estimated and could delay tank retrievals even further.

A second alternative was executed in 1995-1996 using a system designed to combine extraction, packaging, and transport the waste. This system, the Long Length Equipment Retrieval, Packaging and Transport system; referred to as the Rocket Launcher (See Fig. 1), avoided the storage aspects of the wastes and allowed a more direct approach to treatment and disposal. This system consisted of two trailers. One trailer tilted vertically to receive the removed LLCE onto a sled and then was tilted horizontally. This trailer then had to line up with a receiver trailer very precisely for the sled to be loaded, rifled into the receiver trailer tube for final closure and transport to treatment. This system was used successfully in testing only. The Rocket Launcher proved a classic case of an overly complicated technology, operations process, and force fitting a system to a problem that was not yet well defined and did not have enough input from all parties. Specifically, the macro-encapsulation process was complicated by having to now perform treatment on the receiver trailer platform; the mating of the trailers required far more maneuvering room than had been anticipated; the combined weight of the system exceeded several tank dome load limits; and the eighty-foot-long trailer could not be moved into the available disposal trench after treatment for off load. In each case, the resolution created a higher risk from an industrial and radiological safety standpoint, as well as increasing cost. The entire system was mothballed within 18 months.

**Fig. 1. Testing of the Long Length Equipment Retrieval, Packaging, and Transport System**

The next evolution occurred in 2002-2003 with the advent of tank retrieval work beginning in earnest. Tank C-106 was the first tank chosen for full retrieval process to meet the Hanford Tri-Party Agreement milestones for meeting the criteria of an empty tank. In this case, a central pumping system was used to mix tank contents and transport dissolved solids using oxalic acid as the dissolving agent. This system required the removal and treatment of the central tank pump, known as a heel jet pump. However, the modification used at this time was to remove the pump vertically, employ a flushing and rinsing jet system installed on the riser, and load the pump into a transport/disposal package on site for treatment. The Rocket Launcher was re-activated and was used in a modified fashion. The package design was similar to that used for the SY-101 air lances. In this case, the package was 1.5 meters (5 feet) in diameter, 20 meters (65 feet) in length, and weighed nearly 30 metric tons when flooded with grout. However, much of the encapsulation welding could be done on the tube end that would receive the high dose end of the pump, allowing final welding and filling with grout to be done on the opposite, cooler end. The disadvantage was that much of the retrieval tank work had to be halted while the pump was loaded, treated, and finally welded inside the tank farm. This cost nearly 30 schedule days and still resulted in a high treatment cost of nearly $300,000 for one item. Further, placement of the treated waste and container into the disposal trenches required the use of two heavy lift cranes, multiple personnel and extensive off-shift work to allow the effort to be performed safely. Disposal operations and Tank Farms personnel were less than comfortable with the process and determined that some other way must be pursued to more effectively manage this type of equipment.

The next evolution occurred in 2003-2005 with the development of in-field size reduction of oversized equipment. This option was a continued improvement in the removal technologies of equipment, including higher pressure flushing and rinsing systems, as well as a more effective and less costly sleeving process to support removal. These developments reduced dose rates during removals extensively, but two additional problems were encountered.

The first problem was weather. The Hanford Site can reach sub-zero temperatures in the winter and exceed 105 degrees Fahrenheit consistently during the summer. These are less than optimal conditions for workers and created several delays in completing the size reduction activities in a safe manner. Glove bags were also extremely susceptible to failure during the cold periods and created further radiological hazards. These weather delays also led to numerous issues with meeting 90-day requirements for hazardous waste storage under RCRA. Several extension were required by regulators and the DOE to avoid penalties and fines since the Tank Farms are not a permitted Treatment, Storage, and Disposal unit. Five separate requests were required during the fall of 2003, and winter of 2004. Along with the weather delays, some of the wash water would freeze before it had the opportunity to drain, and then created an additional hazard during size reduction, or packaging, as the water melted.

The second problem remained in schedule and cost impacts. Since limited, qualified resources were available for this type of work, and time lines are critical to assure regulatory compliance, work remained impacted on tank retrievals while equipment was size reduced. Additionally, size reduction, while producing a package more amenable to transport and treatment, still resulted in a higher cost per cubic meter that would be encountered if the waste could be directly transported to a processing facility. Routine actual costs for size reduction per piece of equipment were approximately $125,000 along with treatment costs of $4,700/m$^3$. Schedule delays were estimated to impact project performance by nearly $165,000 per item removed from a tank. In some cases, this was two or three items and up to three or four weeks in schedule impact per retrieval. This process, while more amenable to avoiding high treatment cost impacts, still had one other major flaw that needed addressing: exposure of workers to potential high dose fields and potential contamination during size reduction.

Simple adjustments to the approach of schedule discipline processes were performed to solve the 90-day time limit issues. Timing to meet weather restrictions at certain times of the year created better performance, but still were driving items to reach time limits alarmingly close to regulation limits.

**Point of Generation Waste Management**

When the Tank Farm contract was acquired by CH2M HILL in 2001, waste management activities were performed under a central site-wide group. While effective in many ways, the organization did not allow for focused waste management efforts by the generator with direct accountability for executing its regulatory requirements. A system existed wherein tank operations developed a culture that the only way to manage waste was to store it, and let some other project on site worry about the final outcome for treatment and disposal. A more direct approach was required based on experience at several sites, including Rocky Flats and Mound.

The first step in gaining better focus was to create a waste management operation within the framework of the Tank Farms contract. In 2002, Waste Management Operations was chartered, approved by the ORP, and implemented.

A system of Point of Generation waste management began to be implemented. This process ensures that waste should be handled as few times as possible, stored only if no other option remains, and should go directly from the generating point to treatment and disposal as quickly as possible. The shift in culture took time, constant encouragement, and monitoring at all levels. The Hanford Site had become accustomed to packaging mixed wastes and storing them at the CWC, as well as simply storing low-level wastes until it became convenient to process and dispose. The change also required extensive efforts with other site contractors and waste treatment suppliers to create systems and processes that were tailored to the new operation design. By 2004, the shift had been made, as evidenced by removal of all legacy low-level wastes from the tank farms, implementation of size reduction techniques for large equipment for direct treatment, real time inventory control and disposition of wastes, and reduction of waste management costs created by managing large legacy waste volumes. The next phase of the evolution in remote handled waste management was ready to begin.

## TRANSPORTATION AND PACKAGING AS AN INTEGRAL TOOL FOR WASTE MANAGEMENT

In early 2004, the next evolution of waste management in the tank farms was implemented with the creation of the Waste Services (WS) division. The major difference between this function and similar functions, both commercially and in the DOE complex, was the application of a holistic approach to waste management using a hub approach. The hub approach breaks down barriers to traditional approaches so that any aspect of waste management (operations, technical, engineering, packaging, compliance, technical design, strategic and tactical planning, transportation, waste characterization and acceptance, and contract management for waste processes) are managed and operated through a central group that provides service out to projects as customers. This approach allows projects to concentrate on what their missions are, and allows waste management activities to be managed in one area to better control efficiency and compliance as well as a single approach with a single point of responsibility and accountability.

The first efforts of WS were to streamline processes and simplify the application of these processes for project and suppliers. The second major effort was to identify what could be done to affect the strategic and tactical vision for making the management of waste safer and cheaper for projects, as well as reducing schedule impacts to project performance. The biggest area of impact remained large and remote handled waste forms. Through this review process, some areas and factors were clearly not going to be changeable. One constant factor was waste treatment and disposal costs were nearly fixed throughout the United States. The market was limited in competition for treatment suppliers in a highly risky and regulated environment, and the Hanford Site was nearly isolated to alternatives for disposal based on litigation, location, and the myriad of radionuclide concentrations that limited alternatives. The second constant factor that was evident suggested the size reduction of large and remote handled waste forms could be managed, but was still fraught with risk to workers and continued to divert resources. The final constant factor was that waste management costs for the tank farms needed to continue to be reduced to support the tank retrieval mission on limited funds each year.

The only real effective way to make any further change in the waste management equation lay in how we managed transportation and packaging, combined with use of industry to participate in innovating processes from the beginning of generation to the disposal phases. Typical views of transport and packaging management are that the processes are highly regulated under Department of Transportation or DOE rules, such as 10 CFR 830, and are expensive and arduous to modify. Upon careful examination of these rules as applied to hazardous and radioactive material transport, a great deal of leeway could be gained by examining the process as a system; not individual parts. As an example, if you want to send a highly contaminated piece of equipment, 4 meters by 4 meters by 3 meters, weighing nearly 8 tons, to a processing or disposal facility, you would have to get a package that was certified to carry this equipment and then find a transport means that could convey it. WS looked into flexible, designed, and certified transport systems. Costs for such systems soon became a major barrier to obtaining the capability required. Several different tools were needed to address the different hazards presented by the different waste forms. A multi-phased plan was created to begin the process of addressing these waste forms with the intent that each success would generate demonstrated savings and improved safety that would justify the expense to move to the next phase.

**Phase 1: Low Level, Large Size Transport System**

As previously mentioned, storage of contaminated equipment at the Tank Farms had become the norm. Hundreds of pieces of equipment used over years of tank operations, salt well pumping, and commencement of retrievals were stored in many locations. A lot of this equipment was very large and would require extensive disassembly to be able to be packaged for processing and disposal. In the summer of 2004, WS and local small businesses experienced in waste treatment, packaging, and transportation held discussions on options that could be applied to address processing of this equipment as waste for disposal. Several options were considered, but an attractive option was that an extensive rail system already existed on the Hanford Site, though currently not used, and a spur was readily available near the treatment and processing supplier's facility. The local transporter developed a rather innovative approach for consideration through application of a modified railcar to create a self-contained transporter/container. The treatment supplier also worked with city officials and regulatory authorities and was willing to obtain necessary approvals to use the rail spur as a staging point for receipt and off-loading of rail shipments. WS agreed to the approaches as long as each vendor was willing to contribute to its area of responsibility at no cost. In return, WS would work with DOE to return the rail system back into service and assure maintenance of the lines. Further, WS would address areas of contaminated track at their expense to assure that the engines and cars be moved more efficiently and not be contaminated and would also renovate some of the larger equipment storage packages for use with rail flat cars to also carry larger waste items.

Implementation of this approach was far more difficult than anticipated. The first target shipment date of December 2004 went by and we still had not completed any of our respective tasks. The small business transporter came up with an excess refrigerated rail car, cut the top out of it for top loading, and installed an innovative lid and closure system constructed from a fermenting tank they had purchased from a local area brewery. The treatment vendor completed their negotiations for approvals and was given heavy lift equipment to use for the first shipment at no cost: a proof of process down payment. WS did complete rail access as promised, though some areas of contamination were much larger than expected and more gravel trucks were required than planned. The large size storage containers were refurbished on schedule and loads already scheduled. In June 2005, the first rail shipment of waste was completed using the officially titled Hanford Rail Waste Transport System (Fig. 2). However, it is known by workers and local businesses as the Beer Can Express, for obvious reasons. Five subsequent shipments have been made using this system, each larger than the last, and is expected to be used a minimum of twice yearly for the foreseeable future. The first shipment alone saved nearly $45,000; the second nearly $125,000. The major portion of those savings are derived from avoiding the expense of field disassembly of equipment for transport, and the inherent safety risks associated with such activities. Additionally, waste management costs could now be reduced with such a new and powerful tool in hand.


**Fig. 2. Load out of Large Equipment on the Beer Can Express**

In two short years, the inventory of obsolete equipment was reduced from nearly 700 pieces to just over 400 pieces at this time, with another 70 scheduled to be processed in fiscal year 2008.

**Phase 2: Remote Handled Waste Treatment/Disposal Options**

Further development of the process continued. As planned, the success of opening rail capability and saving costs resulted in the ability to invest some of those savings into other packaging and transport technologies. The first area pursued included waste forms created during upgrades to tank transfer pits. These pits had become highly contaminated over time and presented severe radiological hazards when upgrading them to meet current regulatory requirements. Several events occurred over time that had contaminated the environment, exposed workers to contamination, and drove extremely stringent controls for packaging and transport of the wastes. The typical removal process and packaging forced workers to come into close contact with the wastes.

In October 2005, Tank Waste Retrieval Operations and WS began planning for a particularly hazardous pit in the SY tank farms. The pit was known to have transfer jumper leaks over several years and, despite repeated rinsing and flushing, still showed dose rates as high as 10 Rem. Operations believed they could remove the jumpers safely using a choreographed multi-crew approach with remote manipulation tools. However, WS believed, based on preliminary data that the wastes were likely to be categorized as Type B under DOT regulation. No package could be located that would meet shipping criteria for this category and exposure of treatment facility personnel during waste processing to such a hazard was not an appropriate option. Further, WS and Operations also felt that packaging in a conventional Type A certified shipping package for direct disposal would expose tank farm workers to the same hazard. This was because the Type A package would require additional field work for packaging to meet void space requirements and would also require stabilization with grout to meet compression criteria as well as LDR criteria for disposal. More welding of the container would also be necessary and create additional exposures. Operations and WS agreed that time was needed to find an option that addressed all these issues.

WS had an advantage in that the Hanford Site, under 10 CFR 830, had a fully implemented and compliant Transportation Safety Document (TSD). It was possible to accomplish certain packaging and shipment activities under equivalency to DOT regulations, Nuclear Regulatory Commission licensing, or alternative controls analyzed for packaging and transport under DOE Standard 3009. The TSD did allow for shipment of Type B quantity wastes in Type A packages if certain criteria were met: dose management in accordance with DOT requirements, double containment of the waste, and administrative controls to reduce the probability of an event that would create an accident scenario that could breach the container. All of these presented challenges, but were compounded by the need to meet LDR and compression criteria for direct disposal.

WS created a concept of a container that was double-walled, with lead shielding sandwiched between the walls, and had an inner and outer lid configuration to meet all the TSD requirements. Additionally, the concept incorporated a method to weld the inner lid to meet LDR without exposing a welder to dose fields and had to be structurally sound enough to meet compression criteria for disposal without stabilization. In addition, it had to be a cost effective alternative to justify the expense of design and construction in very short order.

The approach was to again take the concept to industry and make use of their experience and capability to meet a need. The result, shown in section in Fig. 3, is the Lead Lined Single-Shell Tank Waste Container, or the Shielded Box. Each container is valued at $65,000, constructed of stainless steel with sealed lead shielding, is DOT certified Type A, and weighs approximately 7.5 metric tons empty. Load out and closure for disposal cost approximately $10,000. Use of a comparative Type A box with a traditional approach would create a waste management cost of nearly $125,000. The Shielded Box is clearly not a tool for everyday use, but in the appropriate circumstances, it provides a value that cannot be challenged: worker and environmental protection.

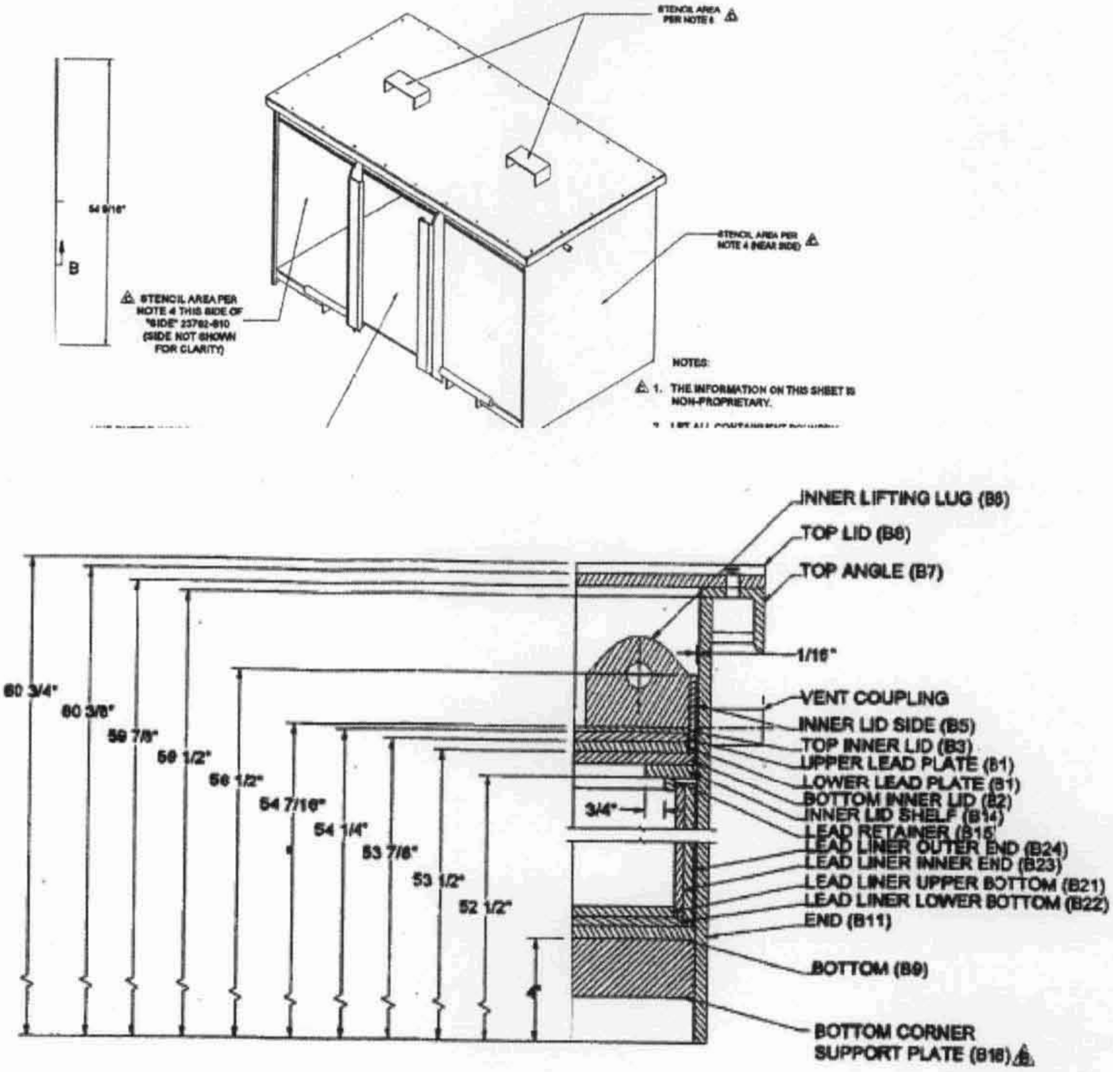


**Fig. 3. Isometric and Section Views of the Lead Lined SST Waste Container**

Four containers were initially procured and constructed and certified for use in May 2006. Operations and WS completed full-scale mock-up training for the process and the SY pit job was commenced in July 2006. The result was a flawless performance, with a dose reduction of nearly 1.5 Rem to workers. All packaging was completed remotely, void filling completed remotely, and the inner lid shielding resulted in virtually no exposure to welding or transport personnel above background. The waste treatment supplier, of course, did not have to expose any workers to the hazard at any time since direct disposal was now possible.

**Phase 3: Back to Long Length Contaminated Equipment**

Of course, the goal of all this effort still had an end state to meet the challenge of improving the management for removed RH and long length contaminated equipment (LLCE) from tanks in a safer, more cost effective manner. In 2005, WS conceived a concept of a transport system that would eliminate the need to perform any field size reduction of such wastes, as well as eliminate any affect from weather, and more effectively separate workers from hazards. Further, the concept would be more cost effective, re-useable, and effectively eliminate schedule impacts to tank retrievals. Discussions and plans were held with Operations to gather input and assess how this concept might work for them. The concept was so radical that it was initially met with a great deal of skepticism. The idea was to create a transport and packaging system that could handle a piece of equipment 18.25 meters in length (60 feet), 1.5 meters (5 feet) in diameter, and weighing in at nearly 4.5 metric tons. Further, the system would be Type A certified under DOT requirements.

WS again went to industry to solicit input as to the practicality of the concept, probability of success, and potential costs associated with the design and construction of such a system. Industry response was also somewhat skeptical. Many industry responses offered to modify existing approved designs for packages ranging from 6 meters (20 feet) to 12 meters (40 feet). Originally, this approach did have potential for success in that costs were significantly reduced in obtaining the equipment, treatment suppliers were used to such standard containers, and substantial reduction in the number of cuts for size reduction would be realized. However, two events occurred in late 2005 and early 2006 that dictated further consideration. Both involved breaches of glove bags during size reduction activities on LLCE and worker contamination events.

Operations and WS staff began to reconsider concepts and another approach to industry was made. In addition, WS also solicited input from treatment suppliers as to their thoughts and ability to manage such materials and process into standard waste packages for treatment and disposal. Three main areas were necessary to address: the packaging had to be done remotely and required a more robust inner package to support double containment and improve contamination control; the transport system had to be certified and designed and built to allow for road transport and rail transport; and the system had to be cost effective, re-usable, and easy to maintain and operate.

Initial estimates by WS indicated that approximately four pieces of LLCE would be removed annually from tanks based on retrieval schedules. Each piece cost between \$125,000 to \$200,000 for in-field size reduction, and schedule delays of three to four weeks on retrievals while resources were diverted to the LLCE processing. Additionally, the cost for treatment at our treatment supplier was costing nearly \$40,000 per item. Design and testing of the transport system was estimated at \$300,000 with construction estimated at \$365,000. The total cost for the system was expected to be recovered in cost savings alone within three years, and had a designed life use of twenty years. Based on this value estimate, the system was approved to be moved forward for procurement in

June 2006. However, due to additional tank retrieval accelerations, the system was needed for its first use in 90 days.

Operations successfully developed an inner packaging system that supported the transport system through an ingenious use of PVC pipe. By simply taking a length of PVC pipe, slicing it in half lengthwise, and placing hinges and latches on the pipe, an inner package was created that would receive the sleeved LLCE. It was cryptically named the Coffin. The treatment supplier personnel could simply lay the coffin on a roller table and remotely cut the LLCE into box-sized pieces for macro-encapsulation. Finally, the transport system would have additional protection against interior contamination as well as meeting the criteria for double containment for Type B shipment quantities, should they be encountered.

The new container system did show several design changes were necessary. The major change was the lid closure mechanisms. The original design was intended to use a screw clamp system that would pinch the lid to the gasket flange. However, during testing and mock-up workers found it would take nearly two hours to complete the closure and torque process; this scenario involved far too much time and exposure probability and an alternative had to found. Again, by searching industry, a system was found that is in use in the marine industry today. By simply adding a set of pockets to the side flange of the lid, cam mechanism was employed to pull the lid down onto the gasket flange. This system could be preset to the required compression values and required only one person to complete the closure in less than 20 minutes. The final cost of the SuperBox transport system was $880,000, which also led us to conclude that one more year of operation would be required to recover the costs for the system. This was still an excellent investment given the life the SuperBox was expected to live and safety it provided.

Design and testing of the transport system did encounter some issues due to the length of the container and meeting appropriate tie-down restrictions. Construction also encountered issues due to the manufacturer having difficulty understanding the precision requirements necessary for such an item. These problems were solved and the LLCE Transport System, or SuperBox, was delivered in October 2006. While concept plans considered single piece equipment packaging and shipment, practical aspects began to show that economies of scale could be realized if multiple pieces could be packaged and shipped in groups. The first shipment of full-size LLCE took place November 2006 and consisted of a salt well screen and a pump from tank C-108 as shown in Fig. 4.

**Fig. 4. C-108 LLCE Loaded in the SuperBox**

The successful implementation of the SuperBox system led to its use more often than anticipated. Continued acceleration in tank closure activities generated 11 pieces of LLCE requiring processing for fiscal year 2007. Through careful integration and planning, all of these pieces were packaged and shipped in five loads. Further, continued efforts with the treatment supplier resulted in additional remote capability for treatment using a remote-operated billet saw, which drove processing time to less than one week for treatment. This allowed WS to negotiate a fixed rate price for each SuperBox load and, while convenient for planning, it required an assurance that the system carried as much as it possibly could to realize the cost efficiencies. Safety improvement was immediately realized as dose projections dropped sharply based on a refined total system for LLCE removal, packaging, transport, and treatment. Remote-handled wastes no longer became the bane of tank farm retrievals and waste items reading as high as 25 Rem were shipped, processed, treated and disposed in the first year of operation. Schedule delays were reduced to just a few days.

As an example, at a realized cost of $125,000 for in-field size reduction of each piece of LLCE in fiscal years 2005 and 2006, plus $40,000 realized cost for treatment of each piece, 11 pieces of LLCE would have cost $1.815 million. However, at a rate of $165,000 per shipment for processing and treatment, and an adder of $125,000 for the 25 Rem piece of LLCE, the realized cost for 11 pieces in fiscal year 2007 was $950,000. The SuperBox concept had recovered its purchase cost in the first year of operation and would allow even further reductions to waste management baseline costs. It has become the current weapon of choice for LLCE.

## LEARNING FROM THE PAST AND LOOKING TO THE FUTURE

The three examples provided above of innovation in the management of large and remote-handled wastes are a beginning. Experience shows that no one tool ever handles all situations. Conversely, attempting to make one tool or process fit all situations will generally fail in a short period of time. The approach used in managing these waste forms is to use a set of tools and processes that fit a large band of waste forms so that flexibility of the systems becomes an ally and increases safe and effective performance. Further, these tools and processes are most effective when they are conceived for long term benefit and attempt to look into assurance that the tools will be effective for many years to come. The concepts are not particularly complex. Many are simply an adaptive use of existing technologies and processes that are generally easy to institute, easy to maintain, and apply a continuing learning of lessons over time.

The effect of these three processes alone has had a positive affect in many other ways. Our workforce, who created and participated in these innovations, take pride in their accomplishments and look forward to each opportunity and challenge in adapting their use. They are proud they have made a real impact on safety and efficiency as well as making visible and recognized change in how these waste forms are managed. This pride has also shown them that they can make change and they are constantly looking for new and effective ways to continue to improve performance. The latest evolution has been a long time in coming as well: use of the Environmental Remediation Disposal Facility for wastes. Several years of effort with regulators and other contractors were pursued to create another long-term pathway for direct disposal of large waste forms in an even simpler way: crush it. This process came on line in July 2007 and ten condemned mobile offices have already been disposed of creating yet more skyline changes and real progress. Plans are in place to remove another 70 pieces of obsolete contaminated equipment to disposal in fiscal year 2008. These types of continuing process innovation also directly affect the bottom line. Fiscal year 2004 base budget costs for waste management in the tank farms, excluding treatment, were nearly $16 million with a total waste processed volume of 1,800 $m^3$. Fiscal year 2007 was completed at a base waste management budget cost of $5.7 million with a total processed waste volume of nearly 5,400 $m^3$, and a total project cost of $7.8 million including treatment and disposal.

Through the use of these processes, partnering with projects and customers, as well as suppliers and industry, all of this work was done and implemented while all the time reducing safety incidents at CH2M HILL to an industry leading level, and achieving the honor for its employees in being recognized by Occupational Hazards magazine at the National Safety Council's Congress in October 2007 as one of 11 of the safest companies in America.